STUDIES OF HADRONIC JETS AND DIRECT PHOTONS AT HIGH TRANSVERSE MOMENTUM WITH THE UA2 DETECTOR

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ABSTRACT

Jet and direct-photon inclusive cross-sections measured by the UA2 experiment at the CERN p$\bar{\text{p}}$ Collider are presented. The data are also compared with the predictions of perturbative QCD. In the two-jet invariant mass distribution, a signal from W and Z hadronic decay has been observed with a statistical significance of $\sim$ 4 standard deviations.

Introduction

We present the results obtained by the UA2 Collaboration at CERN in proton–antiproton collisions at $\sqrt{s} = 630$ GeV in the study of large-p_T jets and photons. We also show evidence for a signal of the process W, Z $\rightarrow$ jj. The data were collected in 1988 and 1989 when, thanks to the new $\bar{\text{p}}$ source at CERN (the ACOL project [1]), the UA2 experiment could collect an integrated luminosity of 7.8 pb^{-1}. The improved UA2 detector was described in detail elsewhere [2], so that here we briefly recall only those parts which were used in the jet and photon measurement:

a) The calorimeter detecting the full azimuthal angle and $|\eta| < 3$, subdivided in a total of 624 cells.

b) The scintillating-fibre detector used for tracking and, in conjunction with a Pb converter ($1.5X_0$), used to measure the position of the early shower with an accuracy of $\sim$ 1.1 mm and 0.4 mm in the axial (z) and the azimuthal directions, respectively.

c) Two arrays of scintillating-counter hodoscopes to measure, with a time-of-flight technique, the longitudinal coordinate of the vertex with a resolution of 25 mm r.m.s.

Jet and direct photon measurement

Jets are defined as a high transverse-energy deposition within a cone of radius

$$R = (\Delta\phi^2 + \Delta\eta^2)^{1/2} = 1.37$$

around the highest-energy clusters. This definition includes also gluons radiated in the final state.

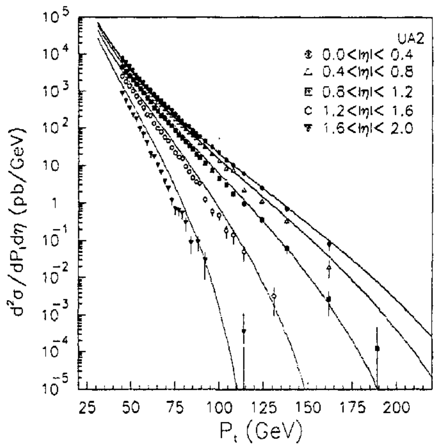

Figure 1: Inclusive jet cross-section at different rapidities of the jet. Solid lines are leading-order QCD predictions with structure functions of [3]. Errors on this plot are only statistical.

The total p_T-independent systematic error amounts to $\pm 32\%$, the largest contribution (25%) coming from the uncertainty in the jet fragmentation function.

Figure 1 shows the inclusive jet cross-section in different slices of rapidity. The solid curves represent an absolute QCD leading-order prediction with $Q^2 = (p_T/2)^2$ and the structure functions

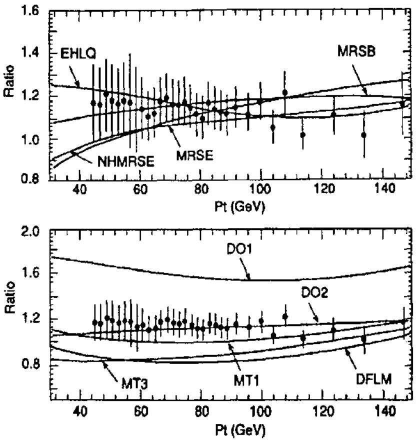

Figure 2: Ratio between UA2 data and QCD prediction using NHMRSB structure functions (data point). The curves are the ratio between predictions using other structure functions [4] and that which uses NHMRSB.

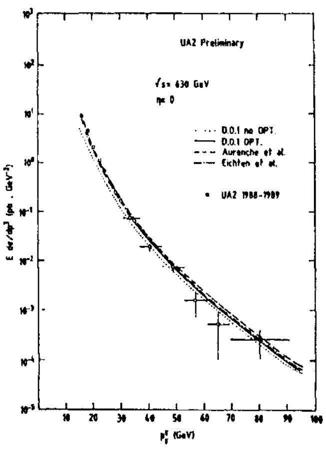

Figure 3: Inclusive direct photon cross-section. The UA2 data (presented with only the statistical errors) are compared with next-to-leading order QCD calculations using different choices of Q^2 and structure functions.

of Ref. [3], set B (NHMRSB). The agreement between data and QCD is good, especially in the central rapidity region.

Figure 2 shows a comparison of the data with QCD calculations, for other choices of structure functions [4]. The data and the QCD calculations are both normalized to the NHMRSB prediction. The agreement between data and QCD ranges within $\sim$ 30%.

In UA2, direct photons are measured in UA2 by the conversion method [5], exploiting the different conversion probabilities in the preshower detector for single photons and for photon pairs coming from π^0/η decays, which constitute a large background to the direct photon signal.

The inclusive direct-photon cross-section is presented in Fig. 3, again in comparison with a QCD calculation performed to the next-to-leading order [6], and for different choices of structure functions (DO1, DO2 [4], Aurenche [7], Eichten [4]) and also different choices of the scale parameter Q^2. There is a general agreement between data and theoretical predictions, but the data are not accurate enough to distinguish the different models.

Two-jet decay of W and Z bosons

The measurement of the two-jet decay of the intermediate bosons [8] represents a challenging experimental issue. In fact, even though the quark–antiquark decay channel is by far more abundant than the leptonic one (by a factor of 6 and 21 respectively for W and Z), the overwhelming QCD background (about 100 times higher than the signal) together with the elusivity of the jet definition make this search very difficult. It is essential for this analysis that there is a large integrated luminosity (the one actually employed was 4.7 pb^{-1}), a dedicated trigger [8], and a jet algorithm to optimize the jet–jet invariant-mass resolution.

The jet was defined by a cone algorithm, i.e. the energy of the jet was collected within a core

$$(\Delta\eta^2 + \Delta\phi) < 0.64$$

whose size was optimized by Monte Carlo simulations and by the data themselves through the minimization of the transverse momentum of the jet pair. The two methods gave consistent results indicating a jet–jet mass resolution

$$(\sigma_{m_{jj}}/m_{jj}) = 10.7\% \, \text{for} \, 70 \leq m_{jj} \leq 100 \, \text{GeV}$$

The jet–jet invariant-mass distribution was analysed, and a good fit of the data was obtained only if, in addition to the function that parametrizes the continuum QCD background, a signal, parametrized as the sum of two Gaussian line shapes, was added in the region $70 \leq m_{jj} \leq 100$ GeV. Figures 4a and 4b show the results of this fit whose free parameters were the W mass m_W, the resolution σ_{mjj}, and the number N of events in the signal. The best fit gave

$$m_W = 79.2 \pm 1.7 \text{GeV}, \sigma_{m_{jj}}/m_{jj} = (9.9 \pm 2.5)\%$$

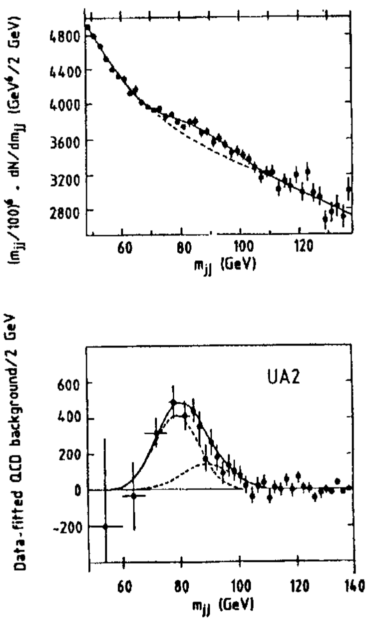

Figure 4: a) Jet–jet invariant-mass distribution. The data are shown together with a fit that incorporates two contributions: a smoothly decreasing function describing the QCD contribution and, superimposed on this in the region $70 < m_{\rm jj} < 100$ GeV, a signal made by two Gaussian line shapes, representing the W/Z → jet–jet. The solid line is the sum of QCD and signal contributions, whilst the dashed line is only QCD. b) Same as a) but the QCD function was subtracted. The separate contributions from W and Z are also shown.

and $N = 5618 \pm 1334$. The number of events found by the fit is significant within 4.2σ and translates into a cross-section times the branching ratio BR into jet pair:

$$\sigma \cdot {\rm BR}({\rm W,Z} \rightarrow {\rm jj}) = 9.6 \pm 2.3\,({\rm stat.}) \pm 1.1\,({\rm syst.})\,{\rm nb}\,.$$

This result can be compared with a Standard Model calculation performed at order α_s^2 [9], which gives 5.8 nb.

References

[1] E. Jones, Proc. 6th Topical Workshop on Proton–Antiproton Collider Physics, Aachen, 1986 (World Scientific, Singapore, 1987), p. 691.

[2] C. Booth (UA2 Collab.), same proceedings as in [1], p. 419.

[3] P.N. Harriman et al., Durham preprint DTP/90–04, RHL/90–007 and the version revised in April 1990.

[4] The structure functions shown for comparison in Fig. 2 are:
E. Eichten et al. (EHLQ), Rev. Mod. Phys. **56** (1984) 579;
A.D. Martin et al. (MRSE, MRSB): Mod. Phys. Lett. **A4** (1989) 1135 and references therein;
P.N. Harriman et al. (NHMRSE, NHMRSB), same reference as in [3];
D.W. Duke and J.F. Owens (DO1, DO2), Phys. Rev. **D30** (1984) 49.
J.C. Morfin and W.K. Tung (MT1, MT3), preprint Fermilab-Pub 90/74, FFT–PHY–90/11.

[5] For a description of the conversion method to measure direct photons see, for example, the UA2 Collaboration publications:
J.A. Appel et al., Phys. Lett. **B176** (1986) 239;
R. Ansari et al., Z. Phys. **C41** (1988) 395.

[6] P. Aurenche et al., Nucl. Phys. **B297** (1988) 661.

[7] P. Aurenche et al., Phys. Rev. **D39** (1989) 3275.

[8] J. Alitti et al. (UA2 Collab.), preprint CERN–PPE/90–105, submitted to Z. Phys. C.

[9] T. Matsuura et al., Z. Phys. **C38** (1988) 623.

Q. **M. Drees** *(CERN)*: Did you include interference between pure QCD graphs and hadronic decays of W and Z bosons?

A. **V. Cavasinni**: Yes, but the effect is not significant, i.e. the signal, defined as the pure $W, Z \to q\bar{q}$ decay contribution, comes out about the same in fits with and without the interference effect. Effectively, most of the interference contribution can be absorbed in the smooth QCD background in the fit where it is not explicitly included.

Q. **L.M. James** *(Univ. of Illinois, Urbana–Champaign)*: Do you have any way in your experiment of filtering for quark jets? If you could prepare a sample enhanced in quark jets, the W/Z peak should be clearer.

A. **V. Cavasinni**: We made an attempt in the past to cut on charged track multiplicity of jets (theoretical prejudices say that it should be higher in gluon fragmentation than in quark fragmentation). We did not get significant improvement on signal-to-background ratio.